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Dated 5 April 2005

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Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form).

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1.	Your reference	EAL/AH-P/6662.GBP
2.	Patent application number *(The Patent Office will fill in this part)*	0407539.6 — 02 APR 2004
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	ATOMISING SYSTEMS LIMITED Unit 8, M1 Distribution Centre Meadowhall Sheffield S9 1EW 8122855001
	Patents ADP number *(if you know it)*	
	If the applicant is a corporate body, give the country/state of its incorporation	GB
4.	Tile of the invention	**Making sintered, iron-based alloy parts by using boron-containing Master Alloys**
5.	Name of your agent *(if you have one)*	*Hulse & Co*
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	*St James House,* *8th Floor* *Vicar Lane* *Sheffield S1 2EX*
	Patents ADP number *(if you know it)*	885002
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	Country — Priority application number *(if you know it)* — Date of filing *(day/month/year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application — Date of filing *(day/month/year*
8.	Is a statement of inventorship and the right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	YES

Title of the Invention

Making sintered, iron-based alloy parts by using boron-containing Master Alloys

Field of the Invention

This invention relates to a method of making high-density (>7.0g/ml) sintered, iron-based alloy parts using boron-containing Master Alloys, and to parts produced by this method.

Background of the Invention

Structural parts of complex shape have been produced for over 50 years by powder metallurgy (PM). The simplest form of this process involves mixing a fine (<150microns) metal (normally iron) powder with a lubricant and also such alloying additions as graphite and copper, pressing a green compact in a die under axial loading, and sintering the resulting part in a reducing atmosphere, typically at around 1120°C. In 2000 this process in all its forms was used to produce about 500,000 tons of parts, the vast majority of which were used in the automobile industry.

Growth of application of the process, which provides complex and precise parts at low cost, is limited by the porosity of the parts, which reduces their properties, especially their dynamic properties such as impact resistance and fatigue strength. For this reason, applications are limited to less heavily loaded parts. To be applied in such parts as transmission gears for cars, a higher density than the currently achievable 7.0-7.2g/ml range is needed, together with suitable alloying to allow surface hardening and heat treatment.

A number of methods have been proposed to achieve higher densities. In powder forging, the sintered part is heated and forged. This raises density to ~100% of solid (~7.8g/ml) but at considerable cost and with some reduction of precision. It has

found significant, but limited application as a result. It is also possible to take the sintered part and press it again to densify, followed by a second sintering operation. This again increases costs, and cannot achieve full density, being limited to the range 7.2-7.4g/ml. The use of high temperature sintering, normally considered as temperatures above 1120°C, the practical limit for mesh-belt furnaces, has also been tried. Temperatures of 1200-1300°C have been used, but costs have been high and the improvements in properties modest. Temperatures of 1180-1250°C are now in common use, but have not, in themselves, enabled the achievement of high density, high dynamic performance parts.

The concept of adding a master alloy (MA) powder as a "sintering aid" to densify the part is well known, and is widely used in the fabrication of tungsten heavy alloy, tungsten carbide etc. However attempts to apply it to iron powder parts have had limited success. The use of ferrophosphorous additions has been quite successful, but the resulting properties tend to be reduced by brittle networks of phosphide. Additionally, work with ferrophosphorous additions required sintering temperatures between 1290°C and 1380°C and ultrahigh carbon additions (0.8 to 2.0) to achieve near full density, as disclosed by US Patent 5,516,483. In the 1970s work in Germany on the use of MCM (metal carbide master alloys) showed great promise, but it was found that the additives, in the form of finely milled carbides of vanadium, chromium, molybdenum and manganese, were extremely abrasive and tool life was drastically degraded, making production uneconomic. In any case these works, aiming at obtaining high strength materials, used double press-double sinter (DPDS) or forging methods for consolidating the PM steels. Single press-single sinter (SPSS) did not lead to materials with higher densities than 7.2 g/cc. A recent report highlighting the use of several Master Alloys

was also directed towards the use of powder forging without attempting to reach high densities by SPSS.

Object of the Invention

A basic object of the invention is the provision of an improved method of making high-density (>7.0g/ml) sintered, iron-based alloy parts, and to parts produced by this method.

Summary of a First Aspect of the Invention

According to a first aspect of the invention, there is provided method of making high-density (>7.0g/ml) sintered, iron-based alloy parts characterised by the steps of:

(i) mixing an atomised boron-containing master alloy powder, or a plurality of master alloy powders at least one of which is boron-containing, with a conventional iron or iron alloy powder; and

(ii) pressing and sintering the mix to an increased density to produce the part required.

Summary of a Second Aspect of the Invention

A second aspect of the invention is directed to high density, sintered, iron-based alloy parts produced by the above defined method.

Advantages of the Invention

The invention provides a new concept where, instead of utilising milled powders as MA additives, an atomised, essentially spherical additive is used. This allows the use of less hard a brittle alloys, as the atomising process does not, like milling, demand a brittle alloy be processed. It also reduces the abrasive nature of the resulting powders, as they do not have the sharp edges characteristic of a milled or ground product.

The alloying approach adopted has also been the subject of intensive research,

and MA compositions including a significant level of boron have been developed. As a result it has been possible to reach sintered densities in the range 7.2-7.8 without resorting to forging, DPDS or to extremely high sintering temperatures.

Preferred or Optional Features of the Invention

Before pressing and sintering, graphite is added to the mix in conventional amounts as used in powder metallurgy technology.

Before pressing and sintering, a lubricant is added to the mix in conventional amounts as used in powder metallurgy technology.

The lubricant is a solid.

The lubricant is a liquid.

The lubricant is a solid dissolved in a liquid.

The master alloy powder(s) contains from 1-20% by wt boron.

The master alloy powder(s) has a mean particle size from 1-30 microns, preferably under 20 microns.

Sintering is effected at temperatures in the range 1050°C to 1300°C, preferably below 1200°C.

Sintering is effected in a reducing, inert or vacuum atmosphere.

From < 6% by weight of atomised master alloy powder(s) is mixed with the conventional iron or low alloy powder.

The pressing is cold pressing.

The pressing is warm pressing <300°C.

The pressed density of the part is 6.6-7.4g/ml.

The parts have a boron content above 0.1% by wt.

The parts have a density from 7.2-7.8, preferably 7.4-7.6g/ml.

CLAIMS

1. A method of making high-density (>7.0g/ml) sintered, iron-based alloy parts characterised by the steps of:
   (i) mixing an atomised boron-containing master alloy powder, or a plurality of master alloy powders at least one of which is boron-containing, with a conventional iron or iron alloy powder; and
   (ii) pressing and sintering the mix to an increased density to produce the part required.
2. A method as claimed in Claim 1, wherein before pressing and sintering, graphite is added to the mix in conventional amounts as used in powder metallurgy technology.
3. A method as claimed in Claim 1 or Claim 2, wherein before pressing and sintering, a lubricant is added to the mix in conventional amounts as used in powder metallurgy technology.
4. A method as claimed in Claim 3, wherein the lubricant is a solid.
5. A method as claimed in Claim 3, wherein the lubricant is a liquid.
6. A method as claimed in Claim 3, wherein the lubricant is a solid dissolved in a liquid.
7. A method as claimed in any preceding claim, wherein the master alloy powder(s) contains from 1-20% by wt boron.
8. A method as claimed in any preceding claim, wherein the master alloy powder(s) has a mean particle size from 1-30 microns, preferably under 20 microns.
9. A method in accordance with any preceding claim, wherein the sintering is effected at temperatures in the range 1050°C to 1300°C, and preferably below

1200°C.

10. A method as claimed in any preceding claim, wherein sintering is effected in a reducing, inert or vacuum atmosphere.

11. A method in accordance with any preceding claim, wherein from <6% by weight of atomised master alloy powder(s) is mixed with the conventional iron or low alloy powder.

12. A method in accordance with any preceding claim, wherein the pressing is cold pressing.

13. A method in accordance with any preceding claim, wherein the pressing is warm pressing <300°C.

14. A method in accordance with any preceding claim, wherein the pressed density of the part is 6.6-7.4g/ml.

15. A high-density sintered iron based part made in accordance with the method of any preceding claim.

16. A part as claimed in Claim 15, having a boron content above 0.05% by wt.

17. A part as claimed in Claim 15 or Claim 16, having a density from 7.2-7.8, preferably 7.4-7.6g/ml.

ABSTRACT

Making sintered, iron-based alloy parts by using boron-containing Master Alloys.

A method of making high-density (>7.0g/ml) sintered iron-based alloy parts by using boron-containing Master Alloys comprises the steps of mixing an atomised, boron-containing master alloy powder, or a plurality of master alloy powders at least one of which is boron-containing, with a conventional iron or iron alloy powder; optionally adding graphite and a lubricant in conventional amounts as used in powder metallurgy technology; and pressing and sintering the mix to an increased density, preferably in a reducing, inert or vacuum atmosphere at 1050 to 1300°C, to produce the part required. The invention also includes parts produced by the above defined method.